



ACES

Accelerated Corrosion Expert Simulator

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SUPERIOR TECHNOLOGY



FOR A



SUPERIOR ARMY



RDECOM

TACOM
The Soldier and Ground Systems
Life Cycle Management Command

TARDEC
U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

EC

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Background Information

SBIR Contract (Year 3 of a 3-year effort)

Stakeholders:

Government:

- Army/TARDEC Materials Group
- Army/TARDEC/RDECOM S&M Group
- Navy/USMC

Industry:

- General Motors Proving Grounds (Commercial)
- Oshkosh Truck Corporation (MTVR, JLTV)
- GDIT (MRAP, JLTV, EFV)
- Northrop Grumman (Shipbuilding)

Others:

- GCAS Inc
- Elzly Technology Corp
- RB Corrosion
- University of Akron



ACES Objectives

- Fully Functional Vehicle Corrosion Prediction Simulation Code
- Simulate Coating & Corrosion Performance in Various Scenarios
- Forecast & Display Deterioration of Vehicle System over Time



Accelerated Corrosion Durability Test



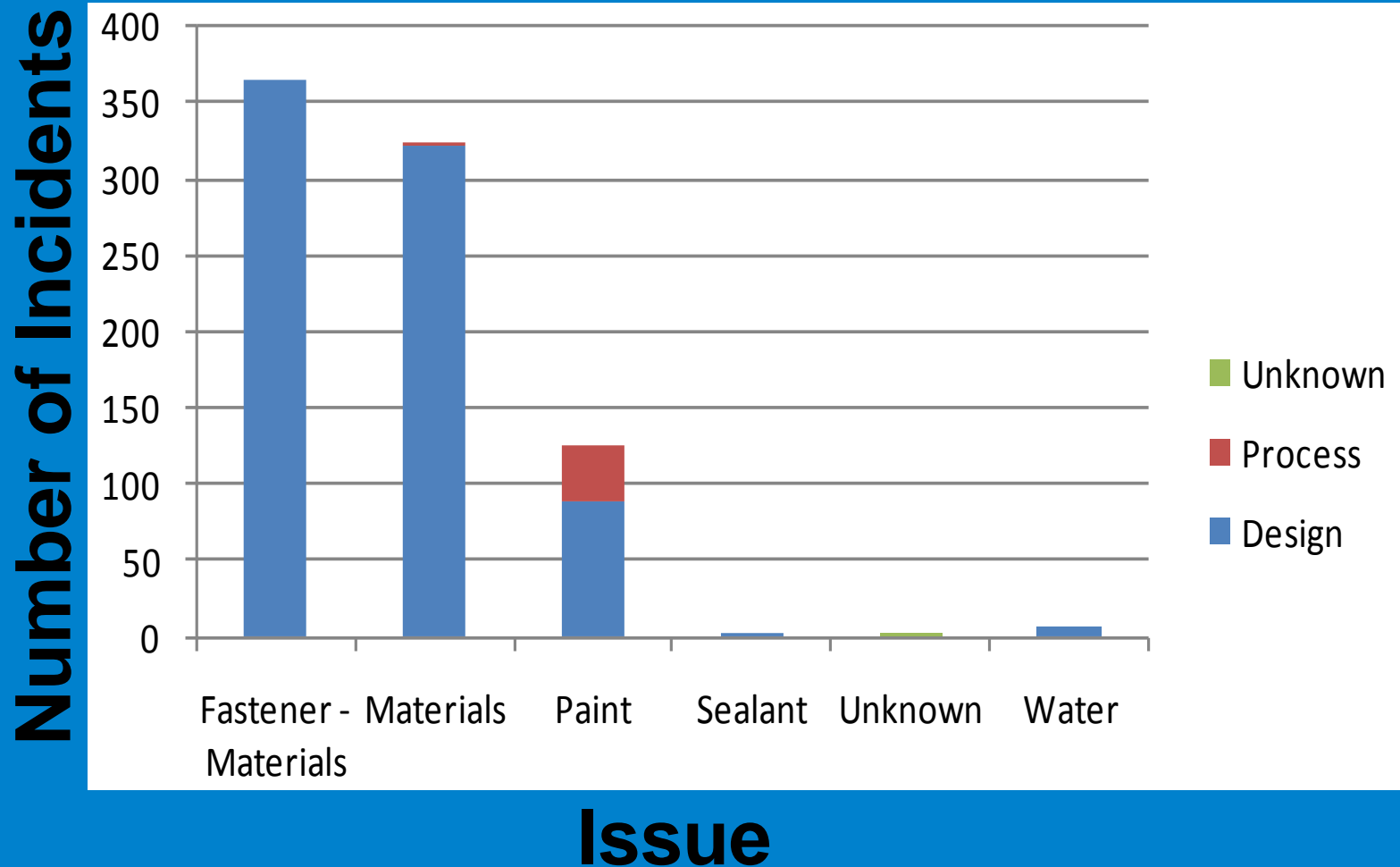
ACDRT





Why do we need a Simulator?

FMTV ACDRT Relationship of Issue and Cause





Full Scale Vehicle Corrosion S&M

- Non-existent for Corrosion Predictions
- Design fixes must wait for ACDRT
- ACDRT is
 - Very Expensive
 - Too Late in the Design Cycle
 - Not Representative of Field Experience for Certain Materials



Advantages of a Simulation Tool?

- Advanced Insight into Potential Problems
- Reduce ACDRT
- Knowledge Retention:
 - ❖ In 3-years = New Hire Graduate Engineer
 - ❖ Continues to learn and get smarter (if Taught!)
 - Lessons Learned
 - Field Experience
 - Validation / Calibration with Test Data
 - ❖ Never Retires
 - 10-years = Expert Tool with Superior Knowledge



Army Materials & USMC Goals

- Determine Compliance of the Design with Contractual Requirements
- Validate that the Design will achieve the desired Service Life



Army S&M Goals

- Armor Impact Methodology Development End-to-End Modeling & Simulation
- Provide Engineering-level & Physics-based Models of Corrosion Degradation to support:
 - Evaluation,
 - Technology down-selects, and
 - Design Optimization
- Probability Distribution showing likelihood to Failure



Industry Goals

Acquire a simulation tool for use in:

- Fast review of Corrosion Vulnerabilities in New Designs
- Assist in Designing Corrosion Tests
- Evaluation of New Technology



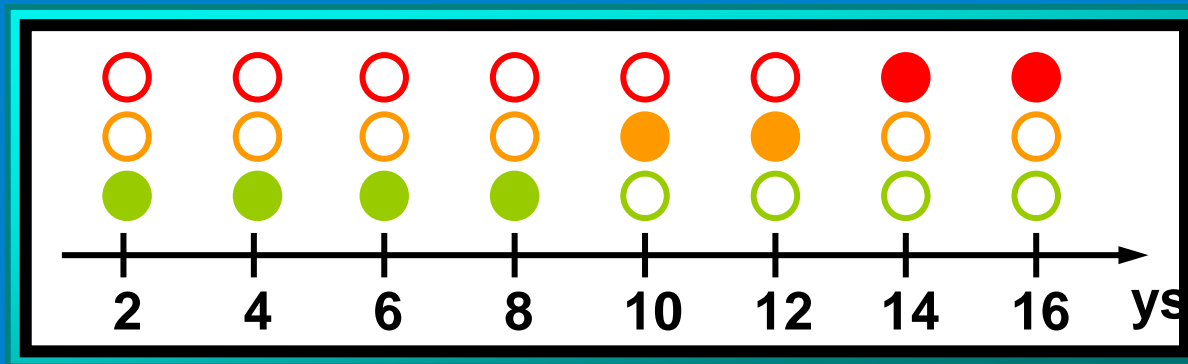
Expected ACES Outcomes

- Specify/Select Optimal Design/Materials during Design/Fabrication of New Vehicles
- Define Maintenance Intervals based on expected Performance
- More Accurate Budget for Coating Repair/ Replacement
- Possible Elimination or Reduction of Full System Corrosion Testing
- Perform “What-if” Analysis on Different Scenarios
- Shorten Product Development Cycle Time
- Realistic Simulation of Corrosion Deterioration over Time



Outputs and Measures Y_j

Risk of Corrosion over Time



- Sensitivity Analysis
- Advisory Capability



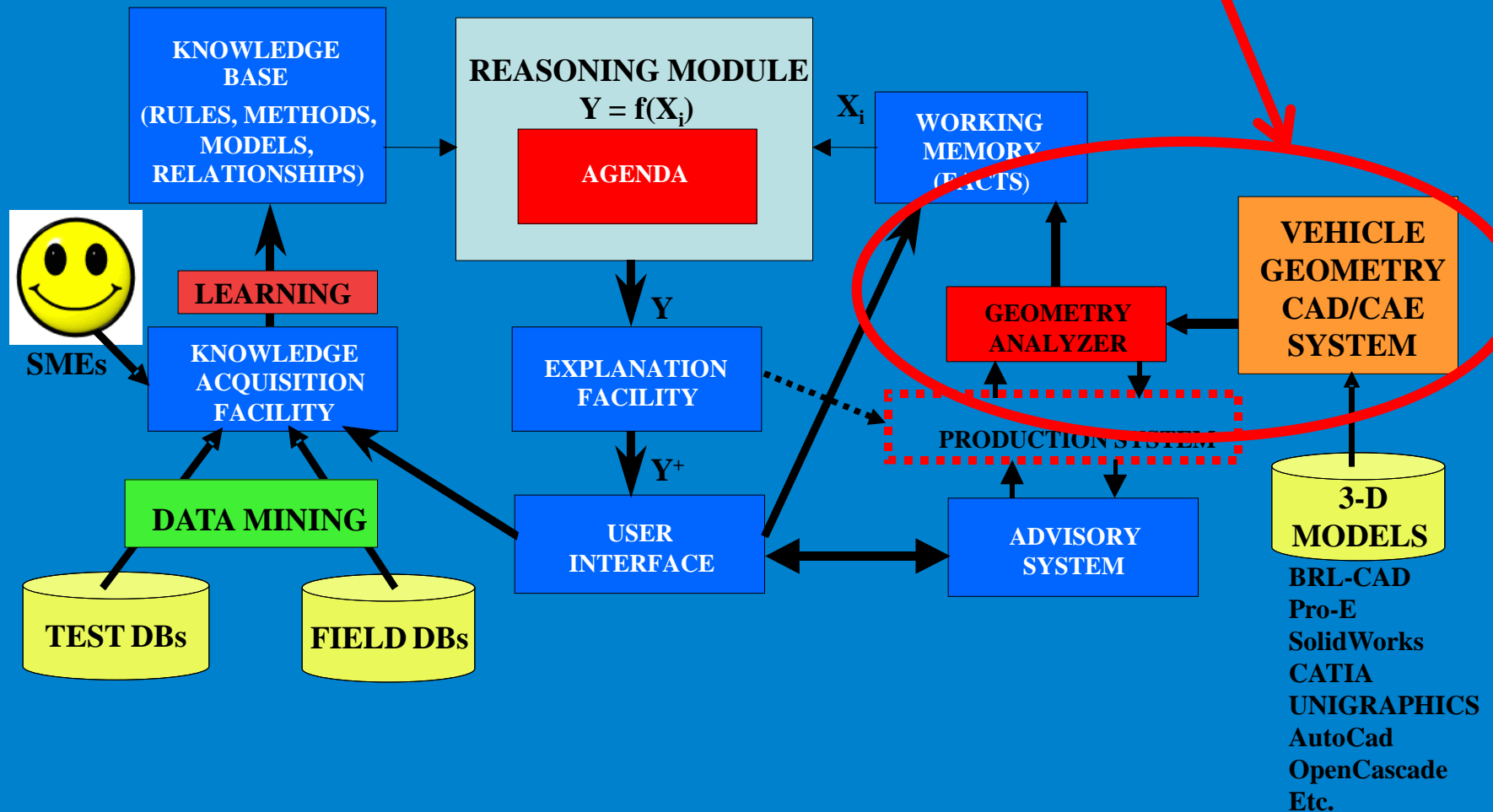
Colorization of HMMWV Model





ACES Architecture

Current Primary Emphasis

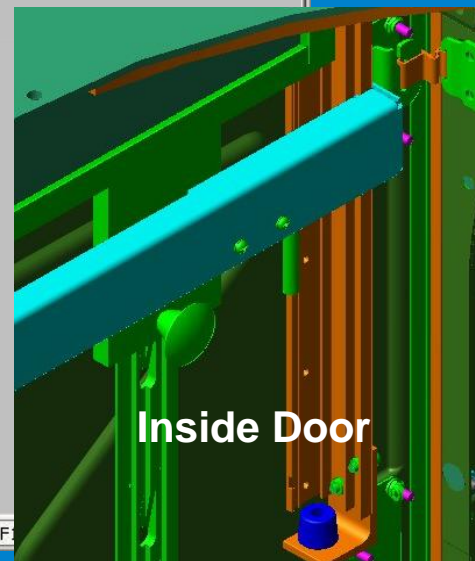
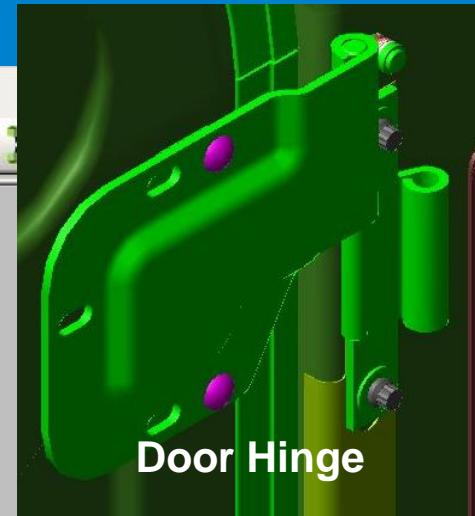
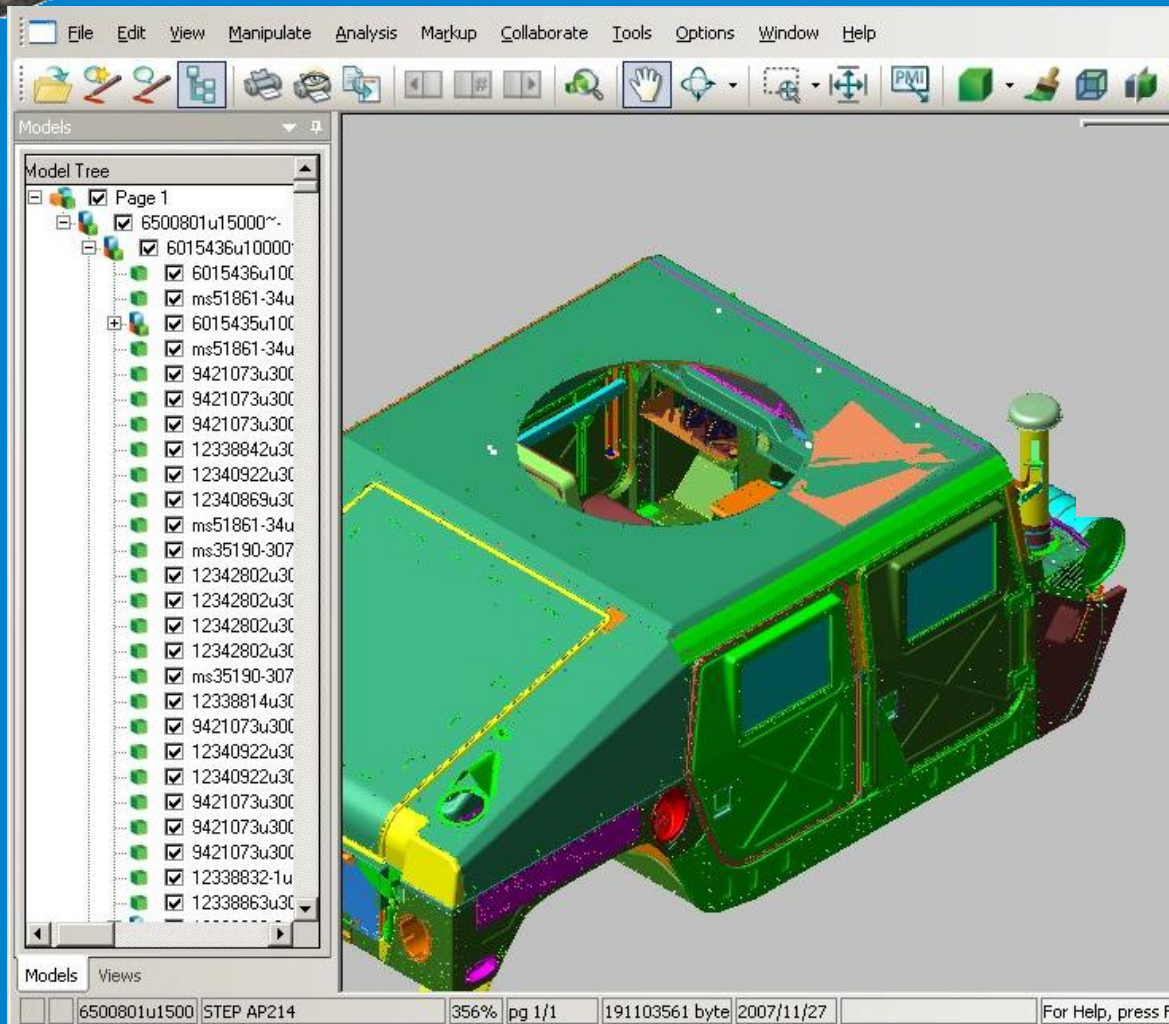




Geometry is Key

- Import from CAD/CAE via STEP-AP214/203
 - Geometry Detail
 - Assembly Process
 - Material Properties
 - Fastener Details
- Other needed data
 - Insulation
 - Lubricants
- Geometry Display and Manipulation

Models have Great Detail



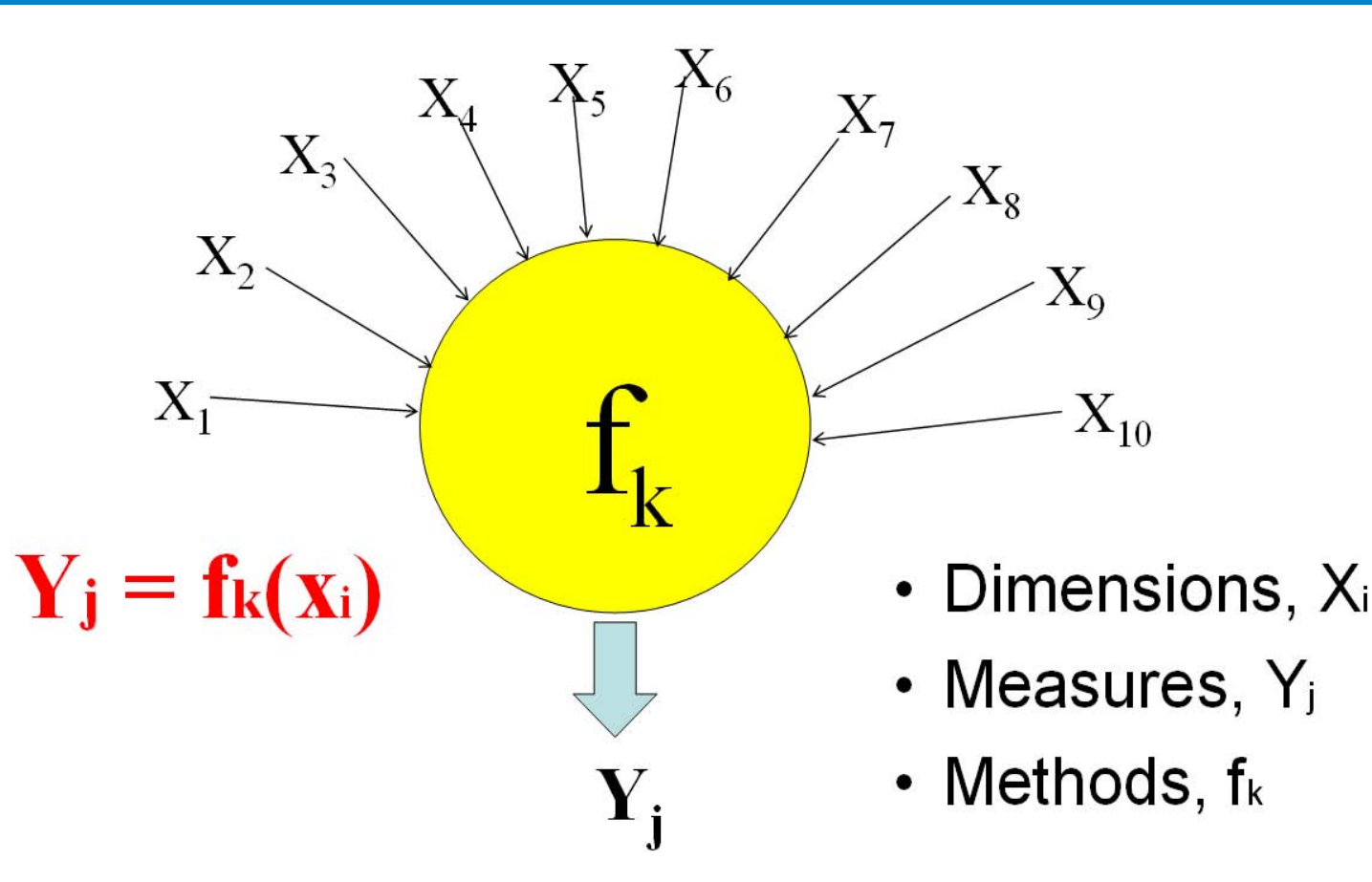


Geometry Analyzer

- Advanced Feature Recognition Software to find Crevices, Entrapment Areas, etc:
 - High Performance Computer (HPC) or
 - Graphic Processing Units (GPU's)
- “Follow the Water” (Water Intrusion/ Drainage)



Modeling Approach





Inputs and Dimensions X_i

Geometry and Design

Lap Joints

Welds

Fasteners

Crevices

Entrapment Areas

Water Intrusion

Drainage

Shielding

Hermetic Seals

Galvanic Coupling

Area Ratio



Inputs and Dimensions X_i

Geometry and Design

Lap Joints
Welds
Fasteners
Crevices
Entrapment Areas
Water Intrusion
Drainage
Shielding
Hermetic Seals
Galvanic Coupling
Area Ratio

Environment

Humidity
Salt Spray
Mud
Fording
Dry Off
Temperature
UV Exposure
Vibration
Shock
Stone Pecking
Driving Miles
Driving Terrain

Maintenance Activities

Wash
Dry
Lubricate
Exercise Joints



Inputs and Dimensions X_i

Geometry and Design

Lap Joints
Welds
Fasteners
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Entrapment Areas
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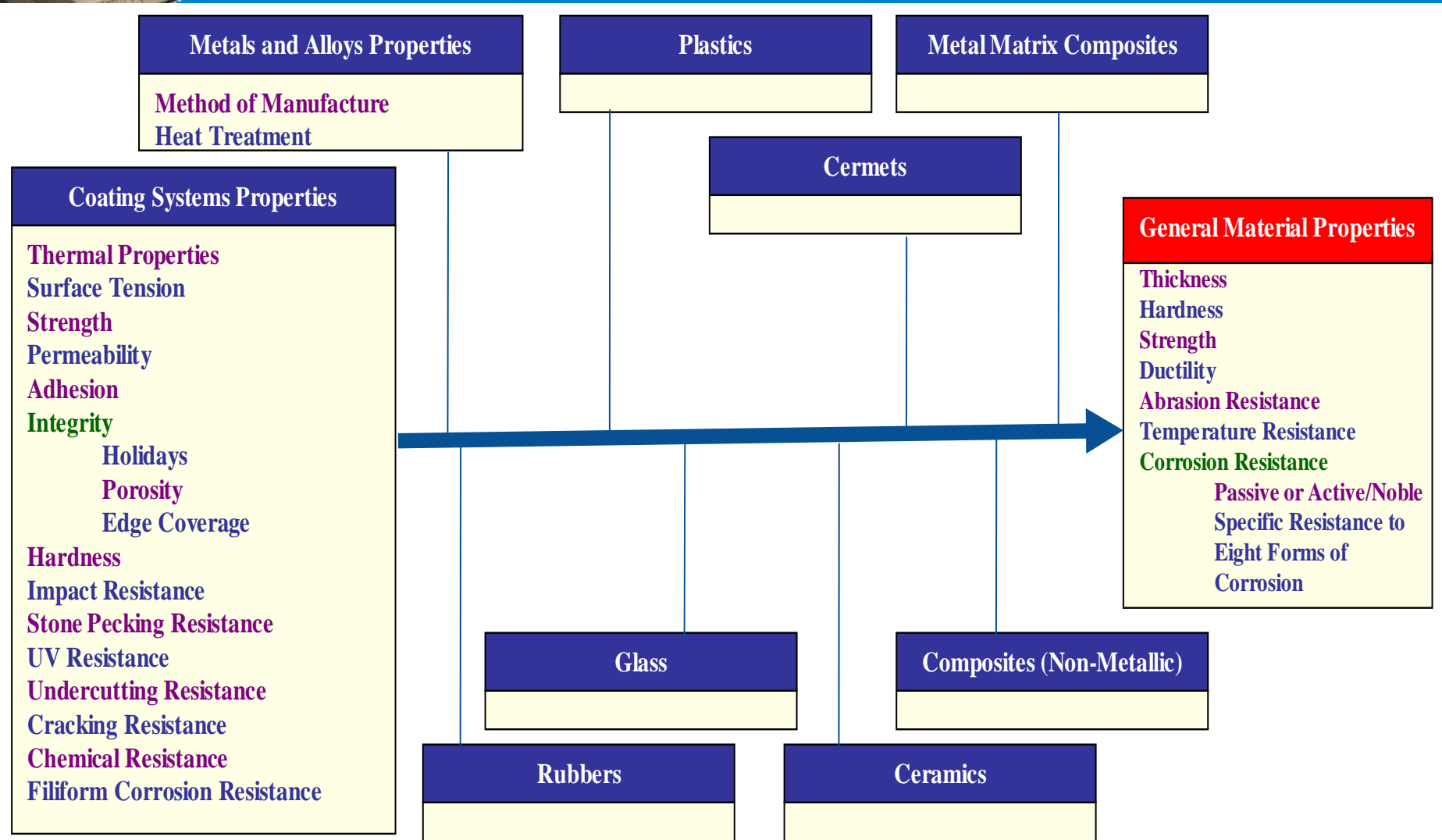
Maintenance Activities

Wash
Dry
Lubricate
Exercise Joints

Materials

Metals and Alloys
Metal Matrix
Composites
Cermets
Non-Metals
Plastics
Rubbers
Glass
Ceramics
Composites
Coating Systems
Organic
Inorganic
Ceramic

Inputs and Dimensions X_i





Models and Methods f_k

Artificial Intelligence

Bayesian Networks

Rule-based Systems

Statistics

Markov Chains

Turnbull / Weibull

Metals and Alloys - Models

General
Galvanic
Pitting
Crevice
Dealloying
Stress Cracking
Erosion
Inter-granular
Exfoliation
Ceramic

Coating Systems - Models

Rust-through
Pinpoint
Irregular Surfaces
Delamination
Undercutting
Corrosion Under Coating
Osmotic Blistering
Peeling
Aesthetic Failure
Color Change
Gloss Loss
Embedded Dirt or Stain
Erosion or Abrasion
Thickness Loss
Texture Change

Fasteners and Hardware - Models

Galvanic
Crevice
Thin/Damaged Plating or Coating
Failure of Isolation Gaskets
Failure of Sealants
Material Metallurgy
Strength-related Failure
Jacking
Seizing
Stress

Electronic Parts - Models

Corrosion in External Connectors
Failures in External Connectors
Corrosion of Electronics
Failure of Electronics

Electrical Parts - Models

Corrosion in Exposed Connectors
Failures in Exposed Connectors



Corrosion Modeling Emphasis

- General Corrosion
- Galvanic Corrosion
- Crevice Corrosion

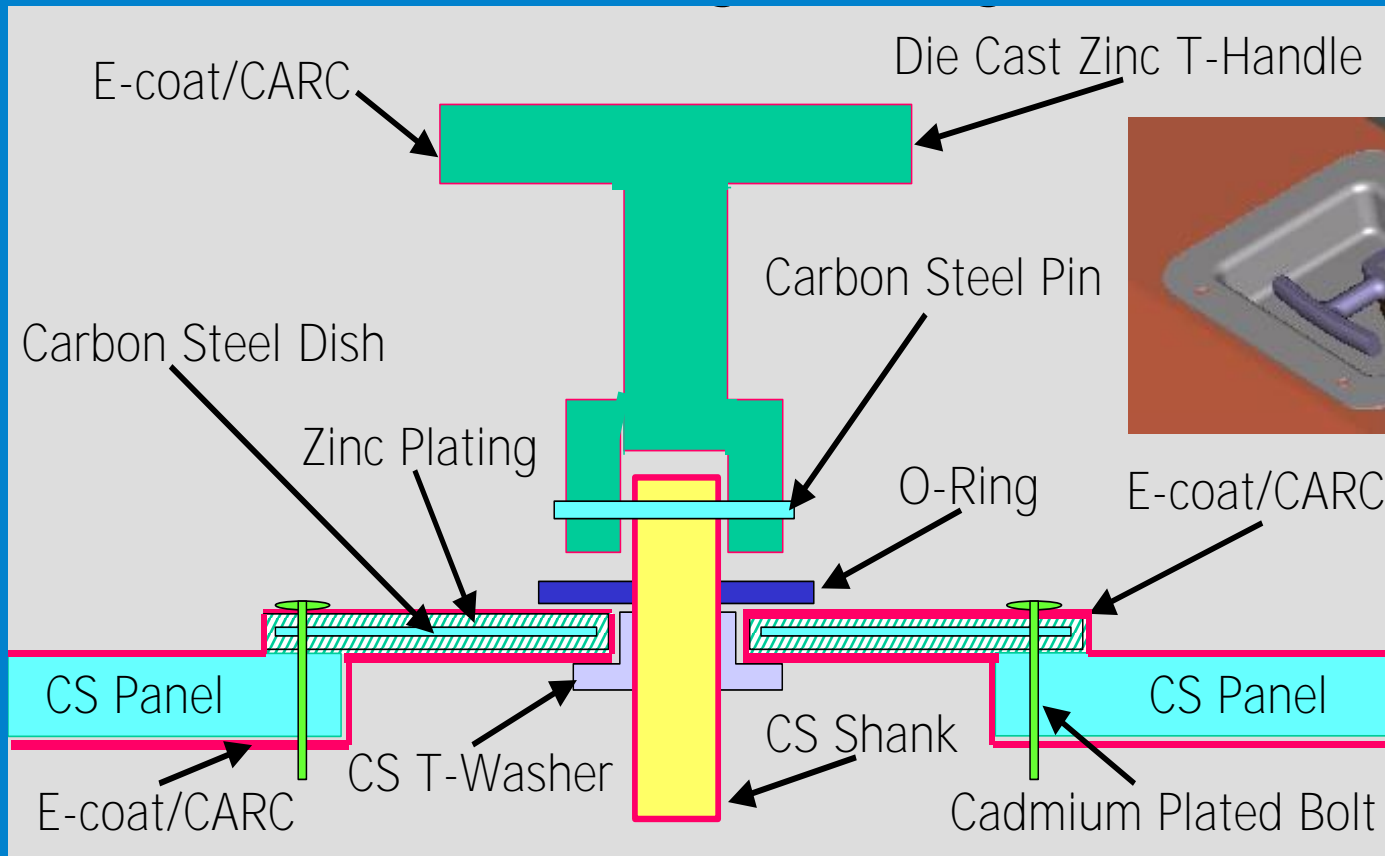


Status to Date

- General Architecture Design
- General Modeling Requirements
- Galvanic Corrosion Modeling (CES)
- Geometry Import, Viewing and Manipulation
- Geometry Analyzer Feature Recognition
- Computational Requirements: HPU/GPU



Original (10-year ACT) Design

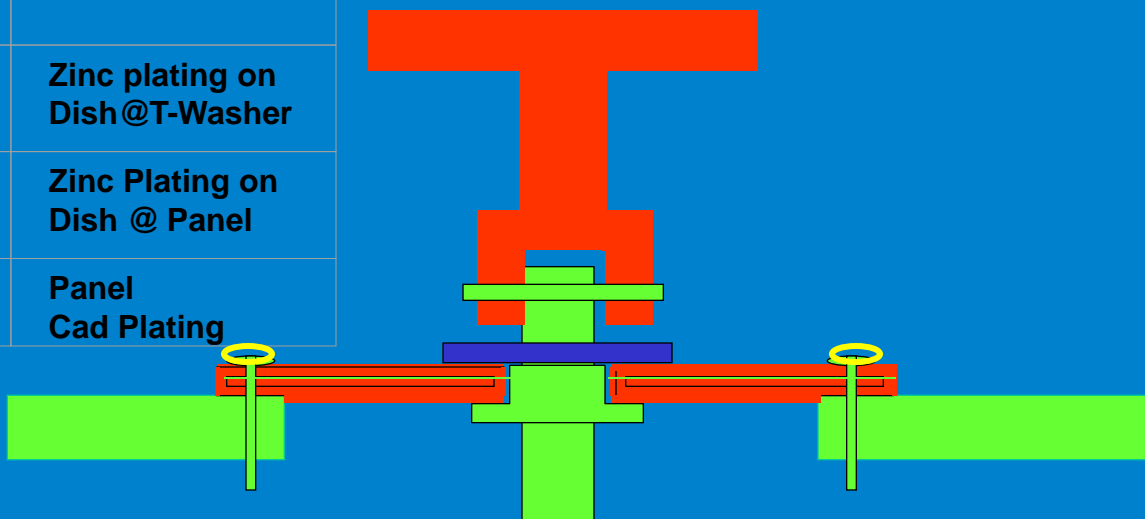




Galvanic Corrosion Predictions

10 yr ACDRT

Interacting Components	Original (10-year ACT) Design	
	Unacceptability	Corroding Part
T-Handle/Pin-Shank & T-Handle/Dish	64.9%	T-Handle
T-Washer/Shank & T-Washer/Dish	11.5%	Zinc plating on Dish@T-Washer
Dish/Panel	59.5%	Zinc Plating on Dish @ Panel
Bolts/Dish & Bolts/Panel	12.8% 30.6%	Panel Cad Plating



Flag Color	Qualitative Assessment	Level of Unacceptable Galvanic Corrosion
Green	<i>Acceptable</i>	Less than 20%
Yellow	<i>Critical</i>	20%-40%
Red	<i>Unacceptable</i>	Greater than 40%



Test Results 10 yr ACDRT

